Collaborative Continuous Benchmarking for HPC

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We benchmark HPC systems for a variety of reasons

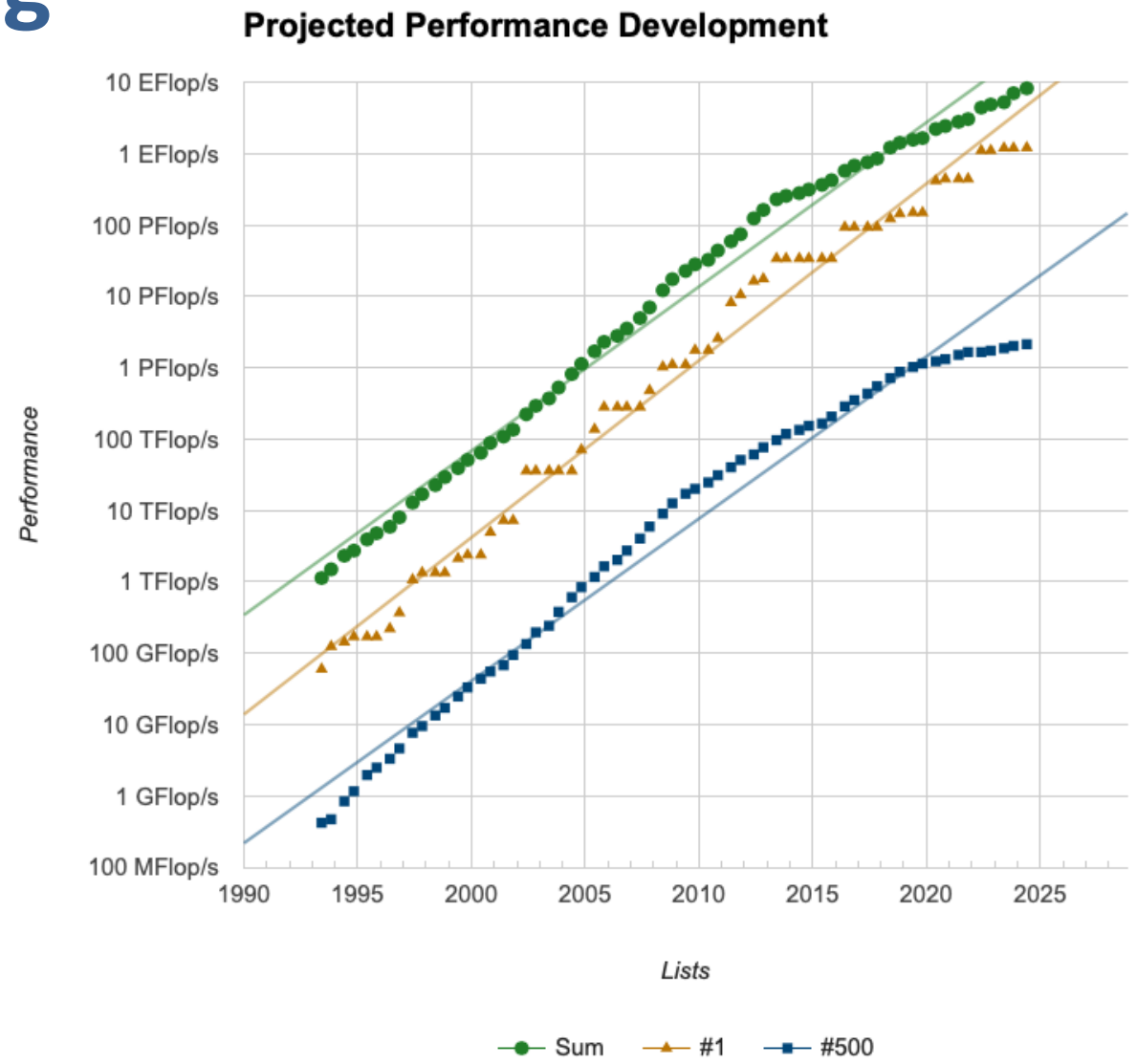
- Procurements
  - *Communicate* datacenter workload to vendors
  - Co-design systems, monitor progress
  - System acceptance (contractual spec
- Validation of software stack, tools
  - Compilers
  - Debuggers
  - Correctness tools
  - Performance tools
- Research
  - Programming models
  - Computational methods
  - Performance across architectures

Many stakeholders, communication is key for collaboration

Source: https://www.top500.org/statistics/perfdevel/

Benchmarking is challenging

- What are we trying to characterize?
- Are we capturing the best the system can do?
- Is something else impacting performance?
- Did we build and run the code in the *optimal* and *reproducible* way?



HPC benchmarks run on diverse HPC systems

Lawrence Berkeley Nat'l Lab
AMD Zen + NVIDIA

F u g a k u
RIKEN **Fujitsu** ARM a64fx

Lawrence Livermore Nat'l Lab
IBM Power9 + NVIDIA

Lawrence Livermore Nat'l Lab
AMD Zen + Radeon

Oak Ridge National Lab
AMD Zen + Radeon

Argonne National Lab
Intel Xeon + Xe

- Benchmark source code
  - Abstraction (OpenMP, RAJA, Kokkos)
  - Hardware-specific (CUDA, ROCm)
- Optimized code for the CPU and GPU
  - Must make effective use of the hardware
  - Can make 10-100x performance difference
- Rely heavily on system packages
  - Need to use optimized communication and MPI libraries that come with machines

Writing benchmark source code is only the beginning

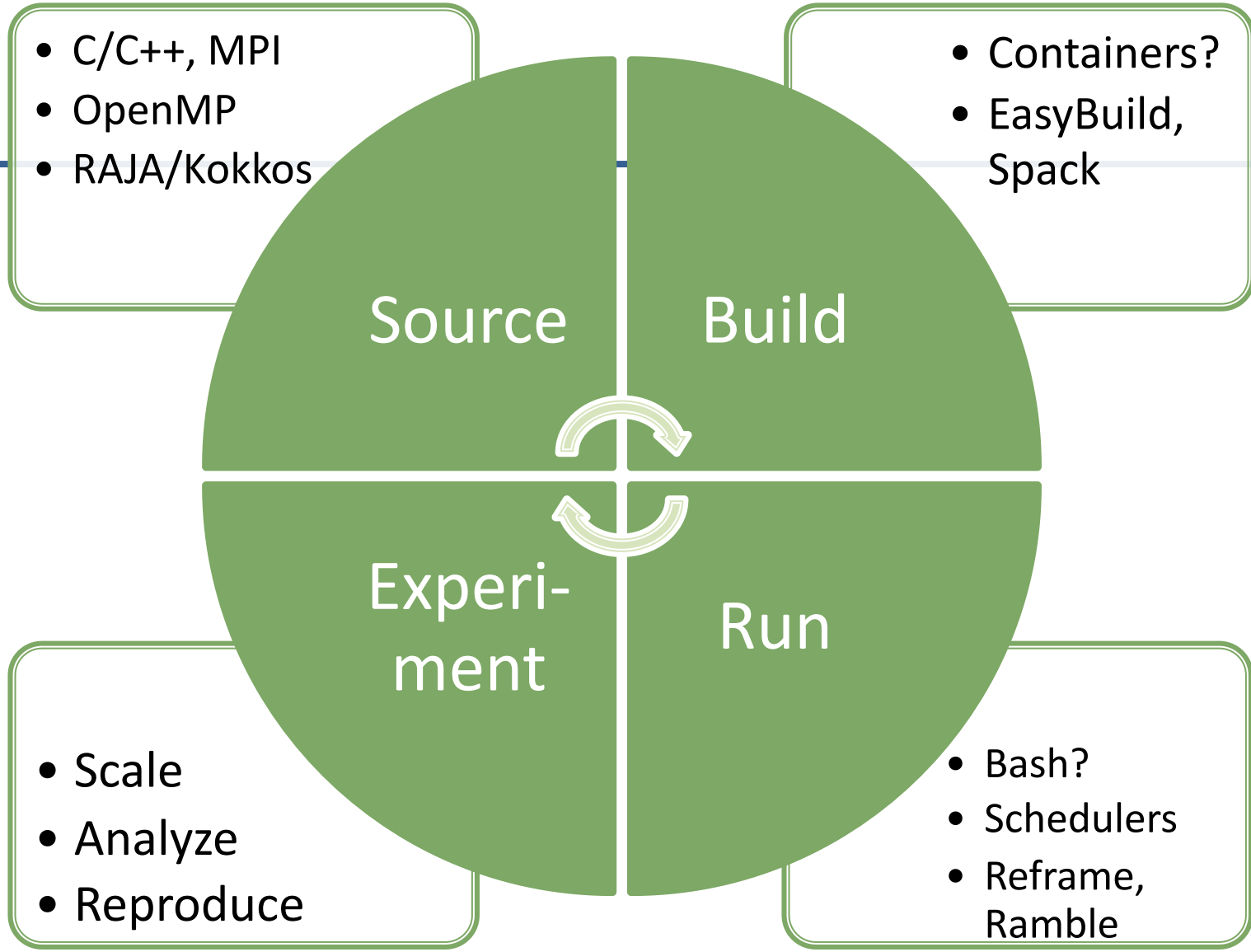
State of the practice:
HPC system benchmarking is manual!

- **Building** on each system is different, porting the builds to new systems is manual
- **Running** on each system is different, porting run scripts to new systems is manual
- Systems keep **changing**, requiring updates to how we build and run benchmarks
- **Triggering** builds and runs is manual: benchmark results don't stay up to date
- **Performance analysis** of results is manual

Communicate technical specification via code, documentation, white papers

HPC Benchmarks are HPC Software

- Portability
- Maintenance
- Testing/CI
- Verification
- Reproducibility



All components must work *for your system*, focus on explainable *performance*

Benchpark enables complete specification of HPC benchmarks

Infrastructure-as-code benchmark specification codifies:

- Benchmark build and run instructions
- **HPC Systems**
- **HPC Experiments**

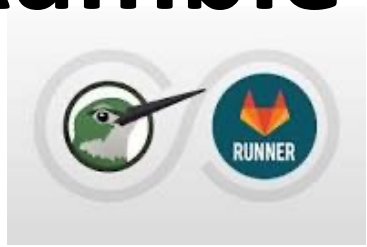
github.com/llnl/benchpark

Leverage advances in HPC automation

- Source code
- Build specification
- Run specification
- CI

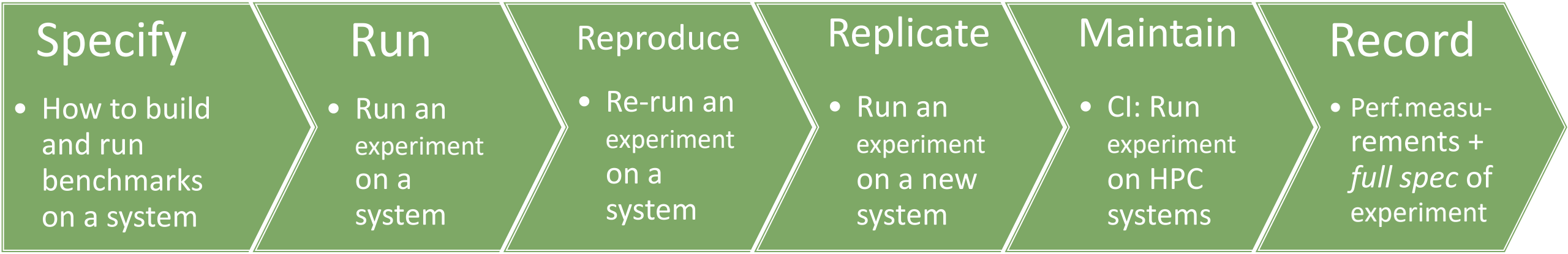
Ramble

Spack



Every part of the specification codified: use to communicate, automate

Benchpark enables *reproducible* specifications of benchmarks



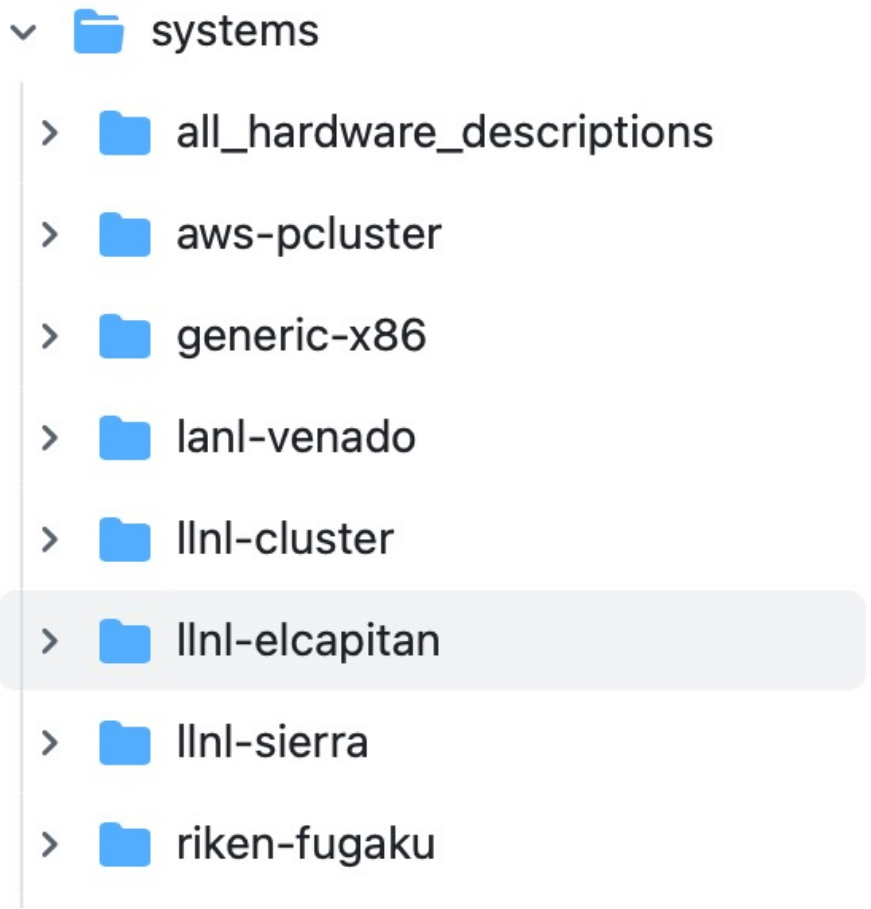
Full specification enables reproducibility, replicability, and automation

HPC System definition for *Performance*

- Resources (CPU cores, GPUs)
- Scheduler (Slurm, *flux*)
- Process mapping (cores, sockets, GPUs, NICs)
- On-node parallelism (CUDA, ROCM, OpenMP)
- Software stack
  - Compilers (which is best?)
  - MPI implementations (best?)
  - Math libraries

Goal: Use the system correctly

HPC System in Benchpark: *Specify Once*




```
class LlnlElcapitan(System):
    variant(
        "rocm",
        default="5.5.1",
        values=("5.4.3", "5.5.1", ”6.2.4"),
        description="ROCm version",
    )

    variant(
        "compiler",
        default="cce",
        values=("gcc", "cce", "rocmcc"),
        description="Which compiler to use",
    )

    def initialize(self):
        super().initialize()
        self.scheduler = "flux"
        self.sys_cores_per_node = "128"
```

./benchpark system init --dest=elcap llnl-elcapitan rocm=6.2.4 compiler=cce

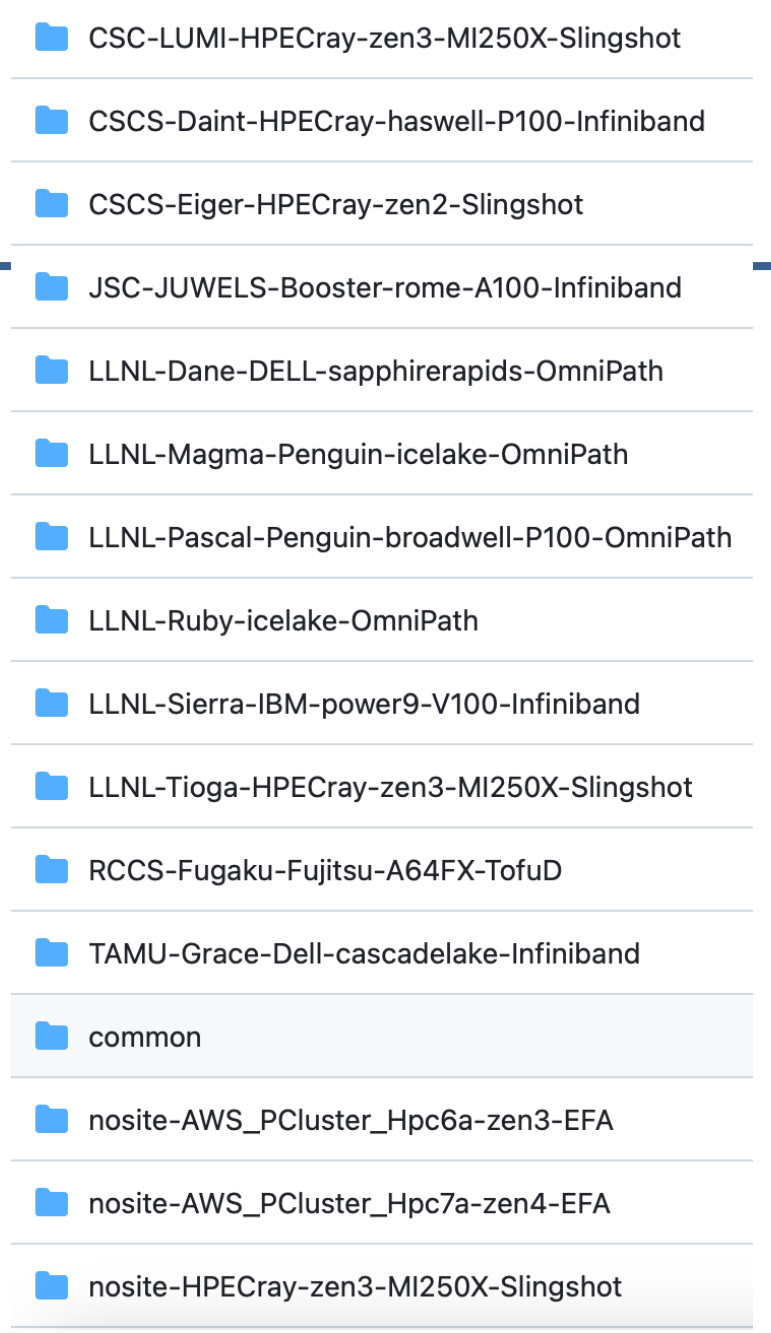
System Specifications

The table below provides a directory of information for systems that have been specified in Benchpark. The column headers in the table below are available for use as the `system` parameter in `Benchpark setup`. See Setting up Benchpark for more details.

	AWS_PCluster_Hpc7a-zen4-EFA	Fugaku	LUMI
site		RIKEN Center for Computational Science	CSC
system	AWS_PCluster_Hpc7a-zen4-EFA	Fujitsu-A64FX-TofuD	HPECray-zen3-MI250X-Slingshot
integrator.vendor	AWS	Fujitsu	HPECray
integrator.name	ParallelCluster3.7.2-Hpc7a	FX1000	EX235a
processor.vendor	AMD	Fujitsu	AMD
processor.name	EPYC-Zen4	A64FX	EPYC-Zen3
processor.ISA	x86_64	Armv8.2-A-SVE	x86_64
processor.uArch	zen4	aarch64	zen3
accelerator.vendor			AMD
accelerator.name			MI250X
accelerator.ISA			GCN
accelerator.uArch			gfx90a
interconnect.vendor	AWS	Fujitsu	HPECray

Systems in Benchpark: February 2025

- 4 in Europe
- 5 in US labs
- 1 in Japan
- 1 at a university
- 2 Cloud systems



HPC Experiment definition for *Performance*

- On-node parallelism (CUDA, ROCM, OpenMP)
- Problem sizes
  - Overall problem size, or
  - Per node or per GPU
- Scaling studies
  - How to scale
  - How to decompose
- Resources (cores, GPUs)

Goal: Specify reproducible sets of experiments that map onto specific Systems

HPC Experiment in Benchpark: *Specify Once*

```
class Amg2023(Experiment, OpenMPExperiment, CudaExperiment, ROCmExperiment,
              StrongScaling, WeakScaling, ThroughputScaling, Caliper):
    variant(
        "workload",
        default="problem1",
        values=("problem1", "problem2"),
        description="problem1 or problem2",
    )

    def compute_applications_section(self):
        scaling_modes = {
            "strong": self.spec.satisfies("+strong"),
            "weak": self.spec.satisfies("+weak"),
            "throughput": self.spec.satisfies("+throughput"),
            "single_node": self.spec.satisfies("+single_node"),
        }
```

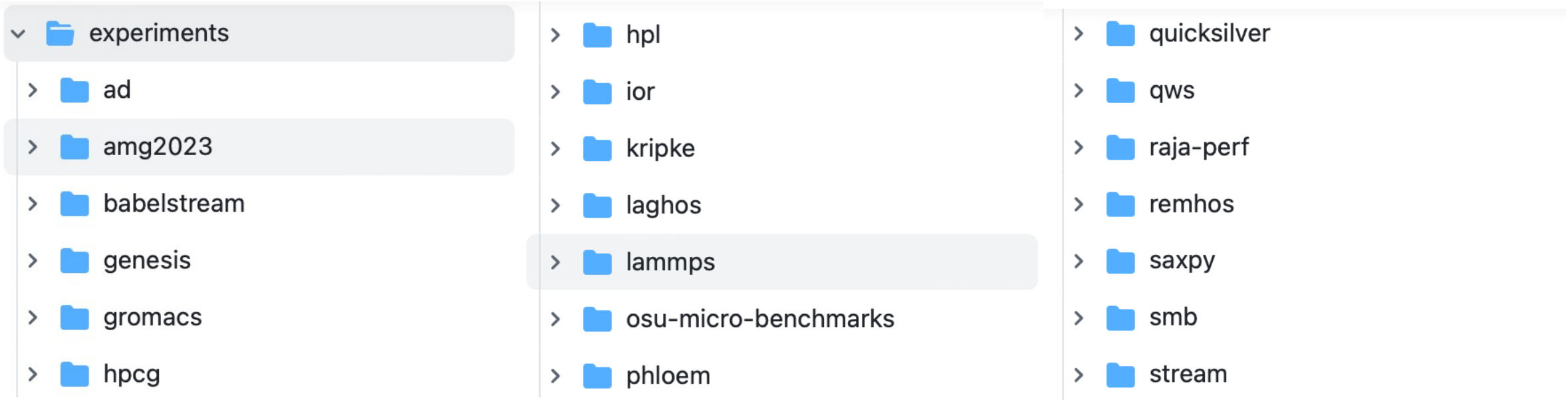
amg2023 +rocm +strong workload=problem2 caliper=mpi,time

Benchmarks and Experiments

	hpl	hpcg	qws
application-domain	['synthetic']	['synthetic']	['qcd
benchmark-scale	['large-scale']	['large-scale']	['we
communication	['mpi']	['mpi']	['mp
communication-performance-characteristics	['network-collectives', 'network-point-to-point']	['network-point-to-point']	[]
compute-performance-characteristics	[]	[]	[]
math-libraries	['blas']	[]	[]
memory-access-characteristics	[]	[]	[]
mesh-representation	[]	[]	[]
method-type	['dense-linear-algebra', 'solver']	['conjugate-gradient', 'solver', 'sparse-linear-algebra']	[]
programming-language	['c']	['c++']	['c++
programming-model	[]	['openmp']	[]

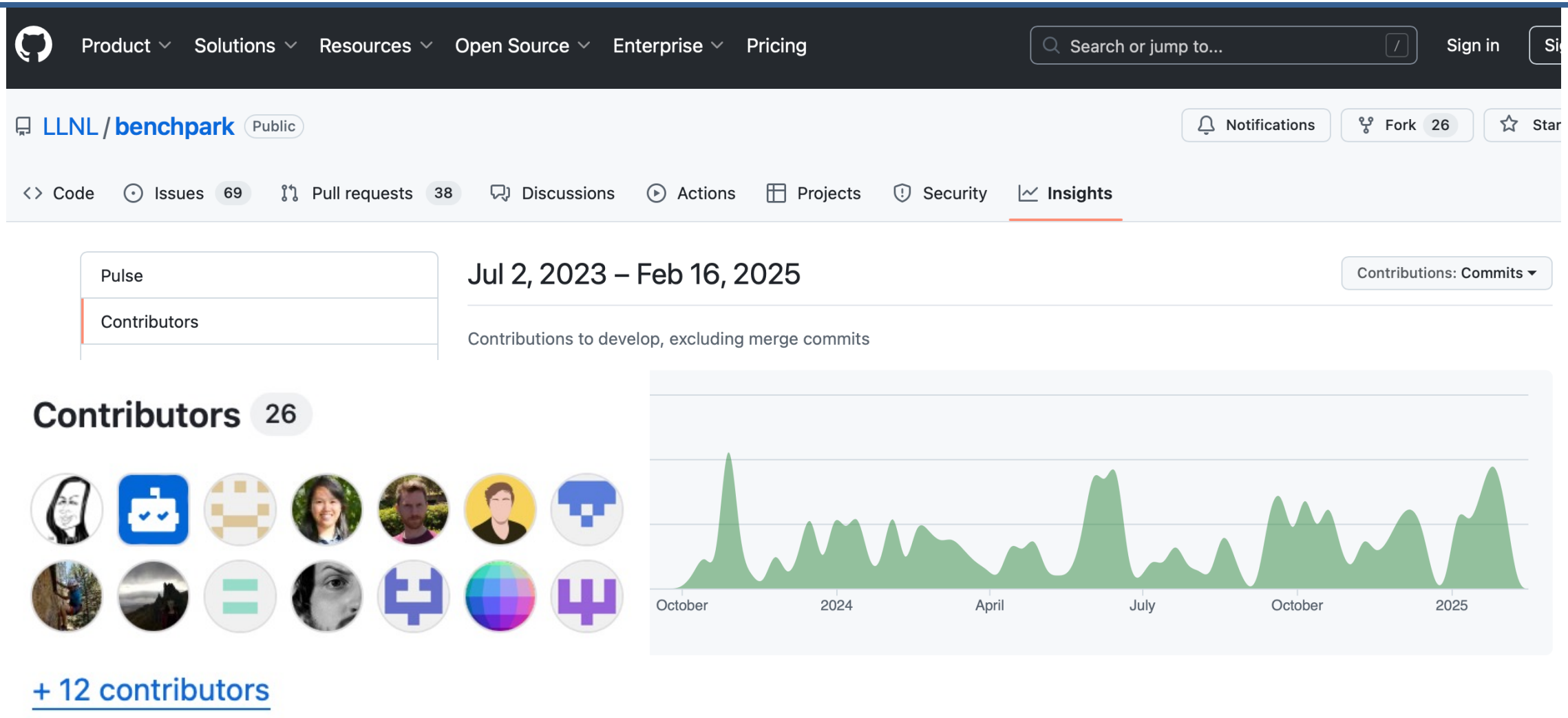
Previous Next

Experiments in Benchpark: February 2025



- HPL, HPCG
- 4 microbenchmarks
- 3 MPI benchmarks
- 8 US
- 1 Europe
- 2 Japan

Benchpark is 18 months old
Contributions from 11 orgs (60% non-LLNL)



Benchpark codifies benchmarking steps

- Benchpark does **not** replace benchmark source, build system, or Spack package
- Benchpark manages benchmark **experiments** and how they map onto **systems** with specified (or default)
  - Compilers
  - MPI/comm libraries
  - Math libraries
- Start running benchmark experiments on your system with just a few commands

```
git clone git@github.com:LLNL/benchpark.git
```

```
benchpark list systems
benchpark system init --dest=elcap llnl-elcapitan
```

```
benchpark list benchmarks
benchpark experiment init dest=amg
                          amg2023+rocm+strong
```

```
benchpark setup amg elcap workspace
ramble workspace setup
```

```
ramble on
```

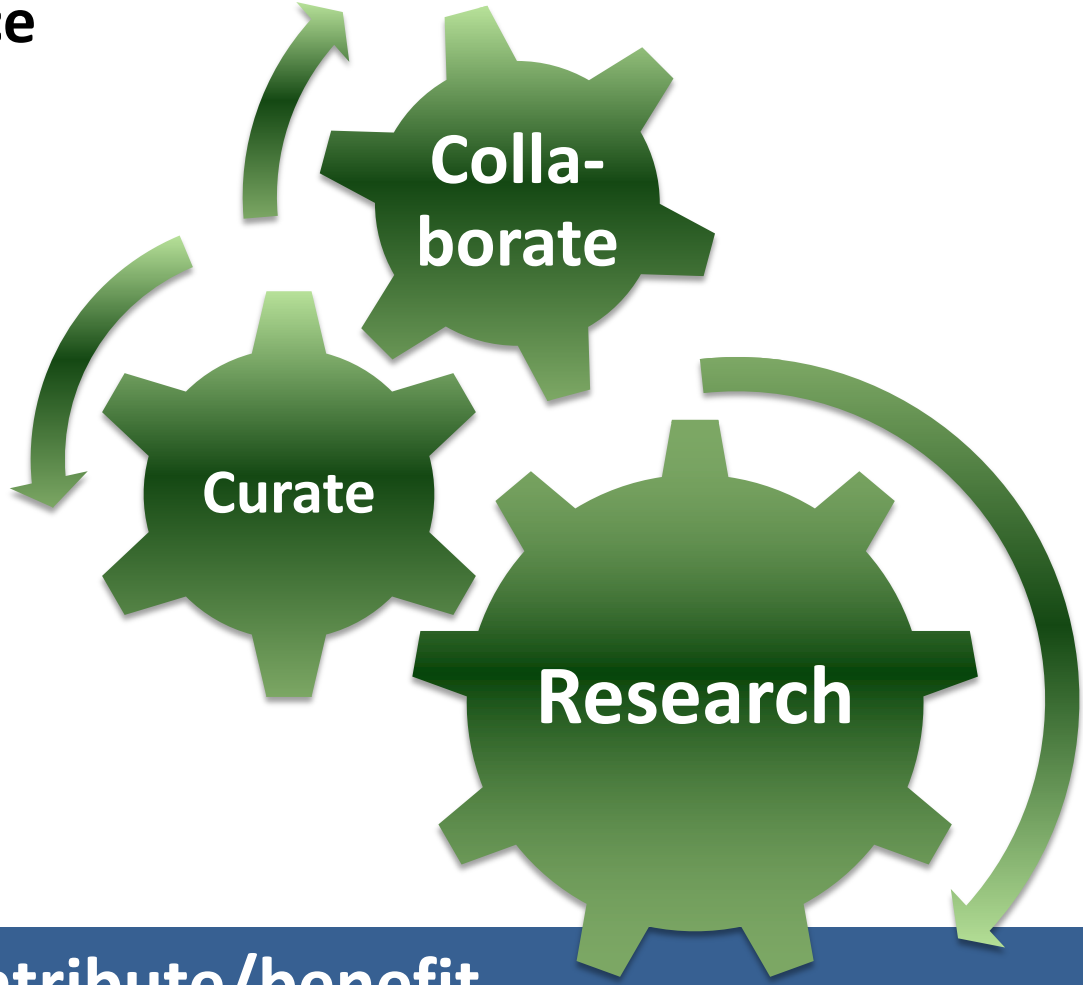
Who can use Benchpark

People who want to use or distribute benchmarks for HPC!

1. **End Users of HPC Benchmarks**
   - Install, run, analyze performance of HPC benchmarks
2. **Benchmark Developers**
   - People who want to share their benchmarks
3. **Procurement teams at HPC Centers**
   - Curate workload representation, evaluate and monitor system progress
4. **HPC Vendors**
   - Understand the curated workload of HPC centers, propose systems

Catalogued library of *working* benchmarks

- **Enables exploration of large configuration space**
  - —Architectural
  - —Software stack
  - —Temporal
- What architecture and system configuration is best for *my benchmark*?
- On *my system*, is OpenMPI good enough?
- What purpose will Benchpark help you address?



Building a community to contribute/benefit

Benchpark: Open collaborative repository for *reproducible* specifications of HPC benchmarks

Infrastructure-as-code benchmark specification enables **reproducibility, replicability, and automation**

- HPC Systems
- HPC Experiments

Specify	Run	Reproduce	Replicate	Maintain	Record
• How to build and run benchmarks on a system	• Run an experiment on a system	• Re-run an experiment on a system	• Run an experiment on a new system	• CI: Run experiment on HPC systems	• Perf.measu-rements + *full spec* of experiment

- Tagging, keywords for publications
- Performance metrics, metrics of usefulness
- Dashboards: Archive specs+results

- CI pipelines on PRs from GitHub at data centers across the world and in the cloud

*Olga Pearce et al, Continuous Benchmarking, HPCTests SC|23

Full specification enables reproducibility, replicability, and automation

Benchpark roadmap and community engagement

Future directions:

- Suite curation: Reproducible specification of an entire suite
- Tagging: Keywords for publications, finding benchmarks
- Metrics: Performance, usefulness
- Dashboards: Archive+share *specs*+results, Slices in configuration space
- CI pipelines at data centers across the world and in the cloud

Community Engagement:

- Co-design / vendors on board, but incentive for app teams? (carrot or stick?)
- Who owns which parts of the specification and approves changes?
- Who finances R&D and maintenance?
- ROI for the people working on it? → think about post docs, researchers, etc.

Collaboration, reproducibility, fully specified public results

CASC

Center for Applied
Scientific Computing

Lawrence Livermore
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